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TOWARDS THE THEORETICAL DETERMINATION OF THE OPTIMAL PROFILE OF A HOLOGRAPHIC GRATING

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16. Abstract

Our aim is to determine theoretically the grating shape constants (slope of the rulings, width of the bottom) in order to get an efficiency similar to that obtained with an echelette grating. By considering various profiles, we arrive at a specific recommendation. A final note refers to the possible use of the grating as a high-pass filter.

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TOWARDS THE THEORETICAL DETERMINATION OF THE OPTIMAL PROFILE OF A HOLOGRAPHIC GRATING

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1. Introduction

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In a previous article [1], we have shown that it is possible to predict theoretically the existence of high efficiencies in holographic gratings; the blaze properties of these gratings have been shown experimentally in the last few years. We now intend to find, numerically, the optimal values of certain parameters whose range of variation has been dictated by the techniques of production.[1]

2. Mathematical Model of the Profile

The electron micrograph already published in this journal [1] agrees with the predictions of the engineers at Jobin-Yvon, in particular with respect to the flatness of the bottom of the rulings; this would be interpreted on the basis of the response curves of the resin used. In order to represent the profile suggested by the picture reproduced in Fig. 1, we have tried three solutions:

(a) A series of line segments (Fig. 1a);
(b) The curve used in our original article (Fig. 1b);
(c) A succession of arcs and line segments (Fig. 1c).

For a Littrow mounting, in order -1, numerical calculations show that the efficiency is not very sensitive to the form of the curve used to represent the ruling profile (Figs. 2 and 3). After discussing the matter with the engineers of the Grating Department of Jobin-Yvon, we have adopted the line segment model in Fig. 1a; this model is very flexible and we can, furthermore, use the method

*Numbers in the margin indicate pagination in the foreign text.

[1]This investigation has been carried out in collaboration with the Jobin-Yvon Company which manufactures holographic gratings.

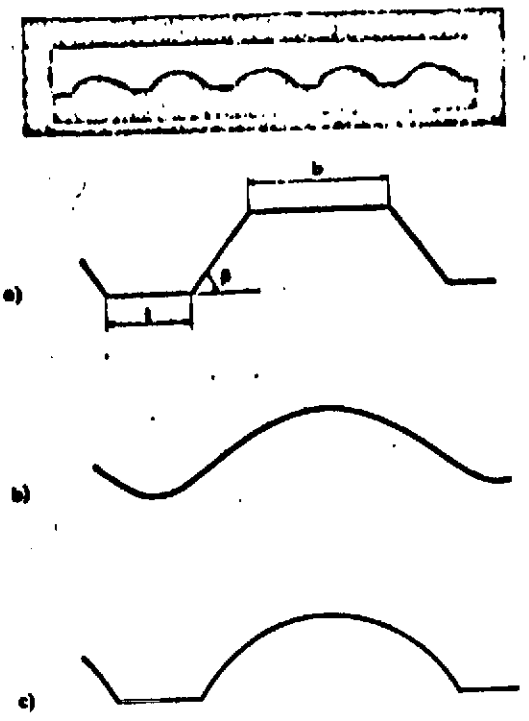

Fig. 1. Mathematical models used to represent the profile of a holographic grating.

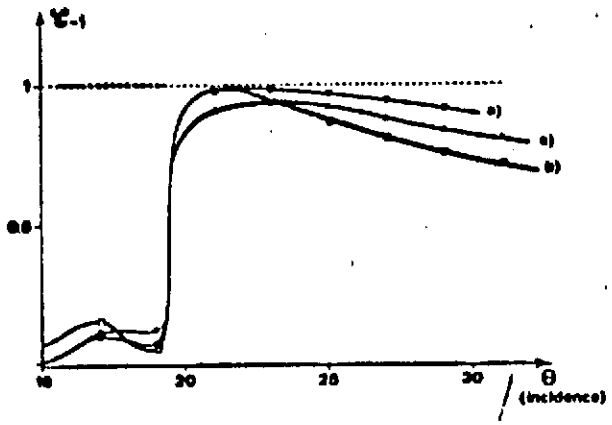

Fig. 2. Comparison of the efficiency curves in a Littrow mounting when the polarization is $H_{||}$.

we had proposed earlier [2].

3. Results for a Littrow Mounting /26

For all the curves shown on Figs. 4 and 5, the depth of the rulings is equal to 1/5 of the grating constant. This particular value was selected on the basis of data published previously [1] and measurements carried out with an electron microscope on standard gratings.

3.1. Influence of the Slope of the Grooves

When the width of the bottom of the groove is equal to half the grating constant, the graphs on Fig. 4 show that tanβ is not a significant parameter.

3.2. Influence of the Width of the Groove Bottom

In order to draw the graphs shown on Fig. 2, tanβ was made equal to 2. The graphs confirm what we had pointed out earlier [1], namely, that holographic gratings can have efficiencies on the same order as those of echelette gratings [3]. For these holographic gratings, we can, of course, give an array of curves which is as complete as the array published on the echelette gratings. In Fig. 5, it will be noted that the holographic grating is extremely

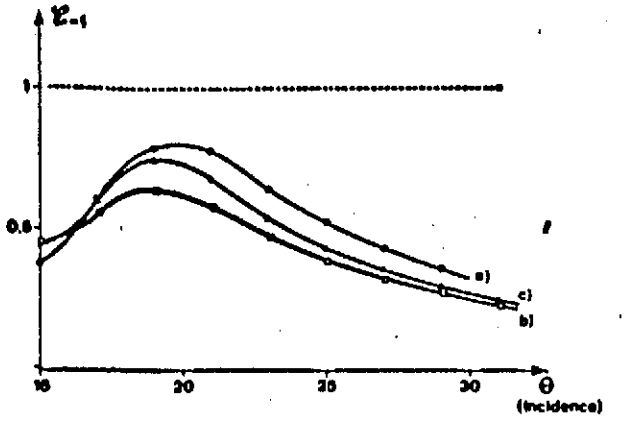

Fig. 3. Comparison of the efficiency curves in a Littrow mounting when the polarization is $E_{||}$.

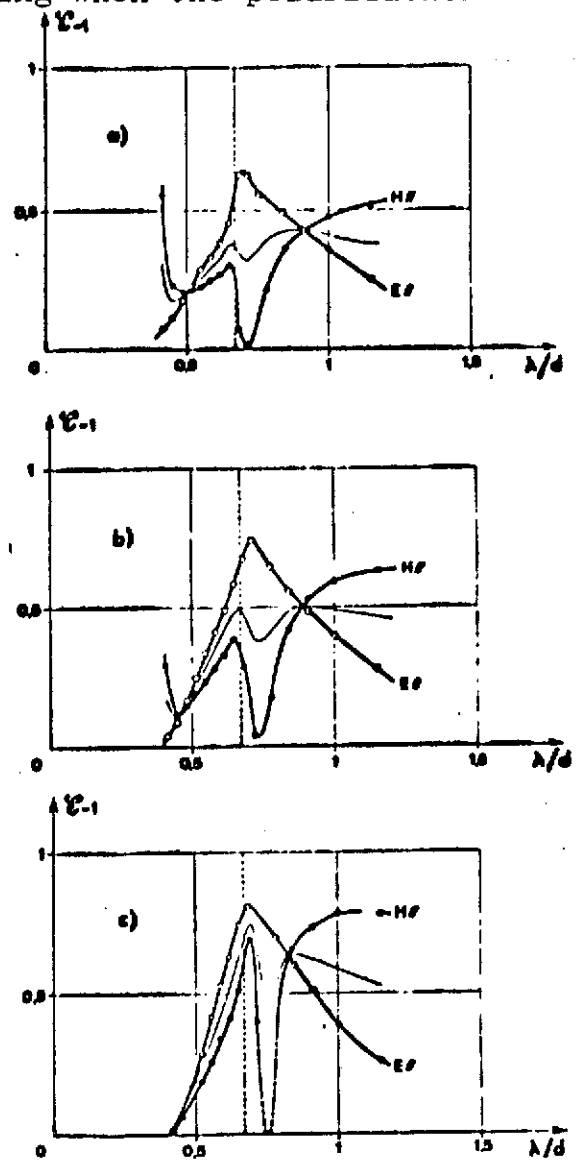

Fig. 4. Influence of the slope of the grooves for $t = \frac{1}{2}d$; (a) $\operatorname{tg}\beta = 1$; $\operatorname{tg}\beta = 1{,}33$; (c) $\operatorname{tg}\beta = 4$.

sensitive to the "Wood abnormality": in the case $H_{||}$, the efficiency drops significantly in the neighborhood of $\lambda/d = 0.67$; this value is often close to where the maximum efficiency /28 is observed in the case $E_{||}$. Fortunately, this drop is constrained within a very narrow range of wavelengths in the case of Fig. 5d, where, moreover, the maxima in the two basic cases of polarization are quite high and occur at neighboring wavelengths. Therefore, one should try to approximate the profile in 5d.

4. Note on the Use as a Wavelength Filter

It appears then that the holographic grating can compete with the traditional echelette grating since it can perform almost as well. In order to check whether this conclusion still holds outside of the case of a Littrow

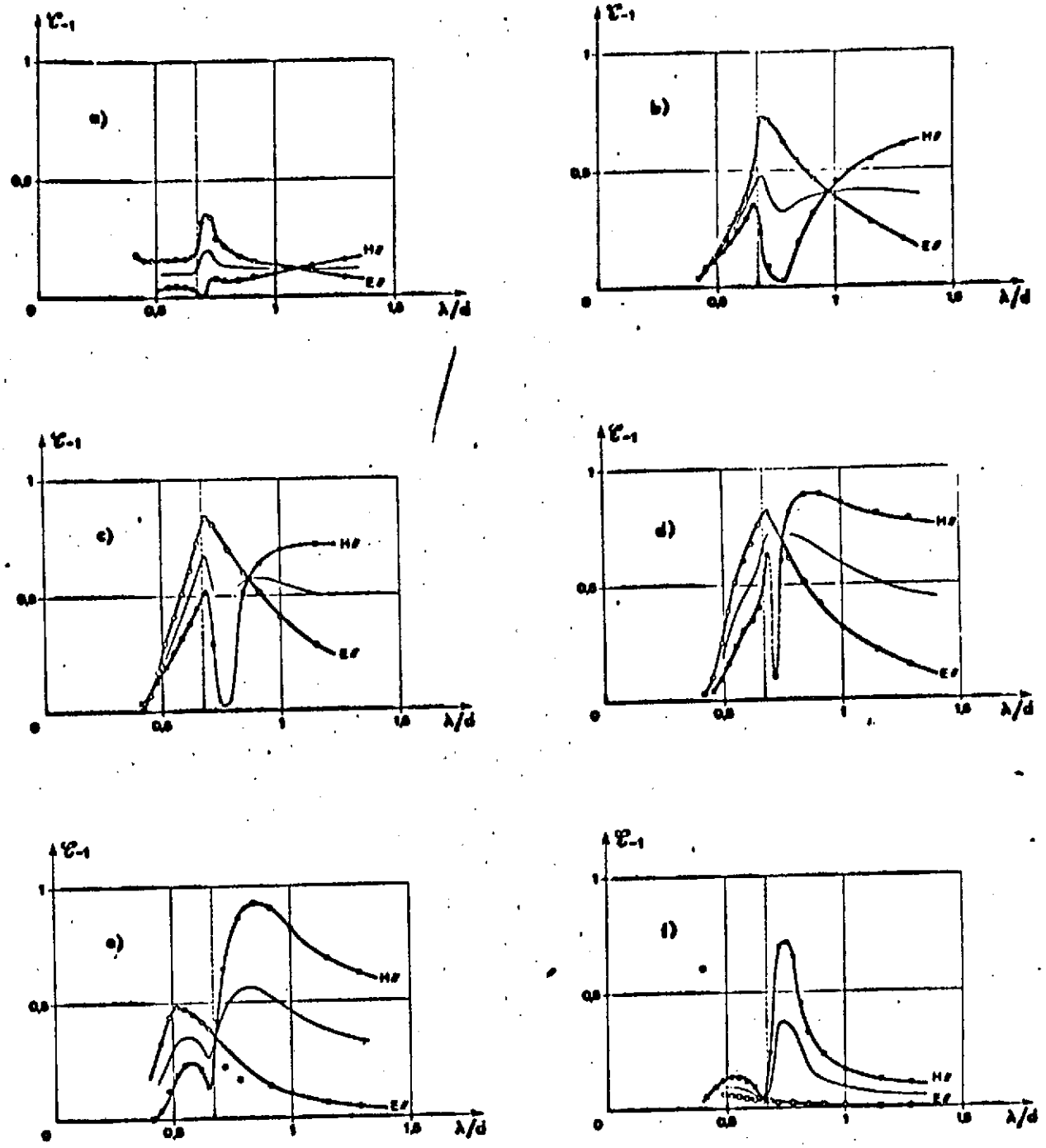

Fig. 5. Influence of the width of the groove bottom for tanβ = 2;
(a) $t = 0{,}8\,d$; (b) $t = 0{,}6\,d$; (c) $t = 0{,}5\,d$; (d) $t = b = 0{,}4\,d$; (e) $t = 0{,}2\,d$; (f) $t = 0$.

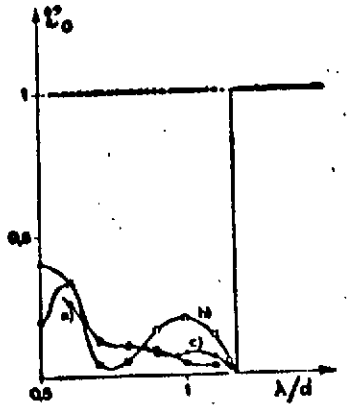

Fig. 6. Comparison of reflecting powers obtained for the three mathematical models in the case $H_{||}$.

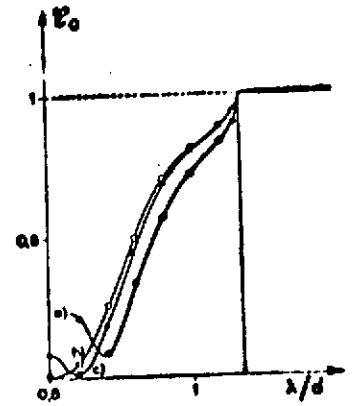

Fig. 7. Comparison of reflecting powers obtained for the three mathematical models in the case $E_{||}$.

mounting, we drew the same curve for the holographic grating as the one published previously for the echelette gratings [4]. For a given angle of incidence, it shows the efficiency in the order zero as the function of λ/d. Figures 6 and 7 show that it does not really matter which model is used and that the basic property observed in echelette gratings is found here also: in the case $H_{||}$, there is a sudden drop in the efficiency above $\lambda = 1.17d$ so that, in this particular case of polarization, the grating can be used as a high-pass filter.

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